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EVALUATION OF AFTI/F-16 RESTRAINT CONCEPTS IN THE ±2Gy ENVIRONMENT

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FOR THE COMMANDER

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The acceleration stresses imposed by the lateral (±Gy) maneuvering capabilities of six-degrees-of-freedom (6DOF) aircraft, such as the AFTI/F-16, may potentially impact pilot performance. This centrifuge research was done to evaluate the effectiveness of special canopy-rail-mounted shoulder restraints at ±2Gy in the presence of a sum-of-sines tracking task implemented via a side stick (force) controller. Results indicate that additional restraints are desirable.

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PREFACE

This is the first in a series of AFTI/F-16 related lateral acceleration pilot performance studies. The Air Force Aerospace Medical Research Laboratory (AFAMRL) and the Flight Dynamics Laboratory of the Air Force Wright Aeronautical Laboratories (AFWAL), Wright-Patterson Air Force Base, Ohio, are undertaking a joint series of studies.

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INTRODUCTION

The advent of six degrees-of-freedom (6DOF) aircraft, typified by the Advanced Fighter Technology Integration F-16 (AFTI/F-16) is accompanied by new and challenging acceleration environments for the pilot. Unlike conventional aircraft, the AFTI/F-16 will be capable of both rotational and translational motions about all three aircraft axes.

A background of experience with 6DOF aircraft was afforded with the prototype AFTI/F-16 and even at the modest levels of ±Gy which that aircraft was capable of generating it became apparent that new approaches to restraint in the ±Gy environment were required. Conventional restraint arrays perform adequately in stabilizing the pilot in the Gx and Gz environment. They are, however, not intended for and are largely ineffective in the Gy environment.

In addition to the basic questions of restraint and body stabilization are the questions of the use of 6DOF maneuvering in the air-to-air and air-to-surface combat arenas. The stability of the pilot in the cockpit impacts these considerations, since inevitably acceleration induced body motions and forces will influence control inputs to the side-arm controller and the rudder pedals and will influence the pilot's ability to keep his line of sight within the exit pupil of his head-up display (HUD), a consideration which is crucial to effectiveness.

In mutual recognition of the challenges involved in these advanced aircraft, the Air Force Aerospace Medical Research Laboratory (AFAMRL) has undertaken a joint program with the AFTI/F-16 Advanced Development Project Office of the Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories. Under this program experiments will be conducted to evaluate not only new restraint concepts, but also the biodynamic effects on the use of rudders and side-arm controller for implementation of Gy commands, as well as studies designed to elicit pilot performance effects in combined accelerations in simulations of air-to-air and air-to-surface combat engagements. The evaluation of an experimental shoulder restraint proposed by the airframe contractor at accelerations of up to ±2Gy was the objective of the experiments described in this report.

The objective of this study was to compare a new restraint system composed of canopy-mounted shoulder restraint pads proposed by General Dynamics, Ft. Worth, with the conventional lap and shoulder harness under lateral acceleration at ±1Gy and ±2Gy on the basis of the subjective reactions of project pilots.

PROCEDURES

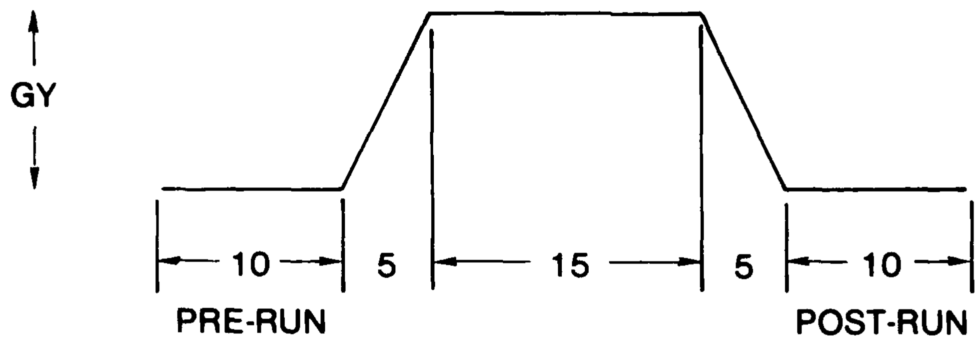
Test Conditions

The experiments were carried out on the AFAMRL Dynamic Environment Simulator, a man-rated centrifuge, which was programmed to produce acceleration profiles by variation in arm speed and cab vectoring as shown in Figure 1. Pilots were tested at both Gy levels while equipped with either the conventional or experimental restraints. At each level of acceleration the pilots were given three exposures in the -Gy direction followed by three exposure in the

-Gy direction followed by three exposures in the +Gy direction. Between exposures the arm and cab motions were arranged to provide $\pm$1Gz. The relationship of the acceleration profile to the tracking task is shown in Figure 1.

During each experimental run the pilots were required to track a display presented on a video monitor representing a 50 mil pipper with a target display moving laterally in random fashion. As shown in Figure 1, tracking data were taken in three epochs: at baseline arm speed, during the acceleration stress, and finally at baseline conditions in the post-stress period.

Data acquired during these experiments included color video cassette recordings, anthropometric measurements on each subject, tracking task error, as well as rudder pedal displacement and pitch axis sidearm controller activity. These latter two data items were not related to the tracking task but were acquired to provide an assay of how the pilots were bracing their bodies against the inertial forces.



TRACKING TASK DURATION-45 SEC

GY	CAB POSITION	INERTIAL EFFECT ON PILOT
+1	0°	PILOT DISPLACED TO HIS LEFT
-1	90°	PILOT DISPLACED TO HIS RIGHT
+2	0°	PILOT DISPLACED TO HIS LEFT
-2	128°	PILOT DISPLACED TO HIS RIGHT

AT 1GY BASELINE ARM SPEED CAB VECTOR ∡ = 45°
AT 2GY BASELINE ARM SPEED CAB VECTOR ∡ = 64°

Figure 1: Relationship of Acceleration Profile and Tracking Task

Subject Population

Six project pilots participated over a 3-day period.

Analysis of Tracking Data

Although the objective of this experiment was to obtain the subjective reactions of the test pilots to the differences between the conventional and experimental restraint systems, certain performance information was obtained from the subjects during the experiments. Long experience has shown that the presence of a performance task during centrifugation reduces the subject's awareness of and sensitivity to the motion artifacts perceived as a result of the curvilinear motion of the centrifuge and gondola.

During these tests, the subjects were presented with a tracking task (open loop) which consisted of a pipper and a simulated stern-on view of an A-10 aircraft. The aircraft and pipper displays were presented on a video monitor in the cockpit, and the disturbing function driving the aircraft display was a sum-of-sines function, active only in the Y axis, comprised of 11 frequencies from 0 to 2 Hz with amplitudes up to 12 radians.

Although not a portion of any performance task, signals were obtained from the F-16 rudder pedals as well as from the pitch axis of the sidestick controller. The rationale for acquiring these signals was that they would be indicative of the pilot's body reactions to the lateral accelerations to which they were being subjected. The uncalibrated data available from the rudder pedals and the pitch axis of the stick indicate that, with a few exceptions, the pilots braced themselves vigorously on the left rudder pedal, irrespective of the level and direction of acceleration. The pitch axis stick data show strong pitchup command forces concurrent with the lateral (roll) axis tracking activity.

During the course of the experiments, the pilots arrived at varying times and were accordingly exposed to the two different restraint systems in a manner dependent upon which system was in place in the gondola. Thus some pilots were exposed first to the various acceleration levels with the conventional restraints, while others first experienced the shoulder pads. Figure 2 shows the ensemble mean and standard deviations of the pilots' tracking scores without regard to the sequence in which they were exposed to the restraints. Figure 2 clearly shows that there are no significant differences in tracking performance as a function of either acceleration level or type of restraint. The data indicate that the pilots first exposed to the shoulder restraint system never attained the tracking proficiency of the pilots first exposed to the accelerations using the conventional restraints (see figure 3).

The remarkable difference between these two sets of data is also shown in Figure 4, which depicts the ensemble mean and standard deviations of tracking performance of the pilots who were exposed first to the conventional restraint system and subsequently to the experimental system. This figure indicates a clear trend toward improved performance at $\pm$2Gy with the shoulder pad restraints.

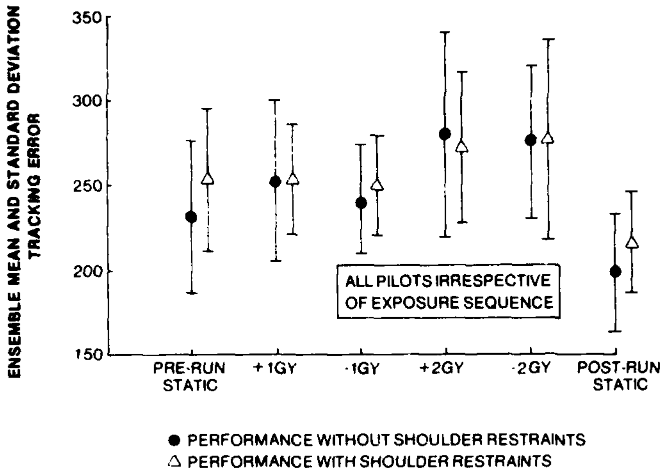


Figure 2
Tracking Error vs Test Conditions
Irrespective of Exposure Sequence

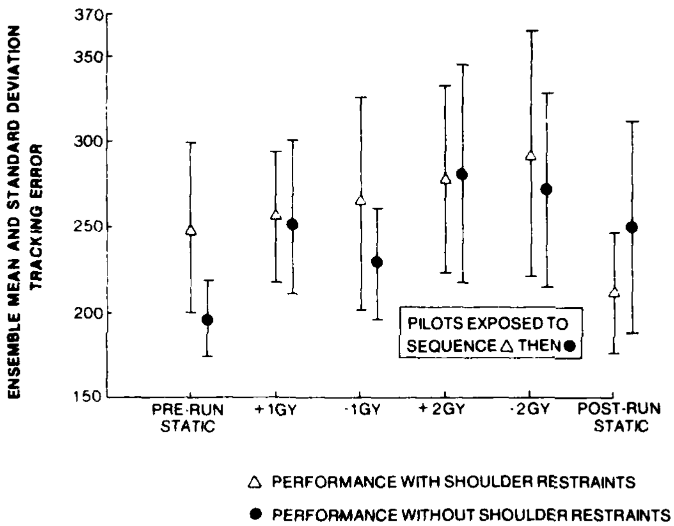


Figure 3
Tracking Error vs Test Conditions
With/Without Shoulder Restraints

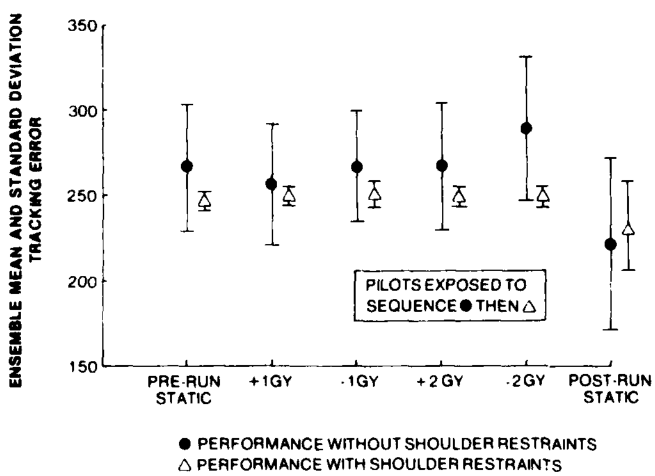


Figure 4
Tracking Error vs Test Conditions
Without/With Shoulder Restraints

This trend is supported by $\underline{t}$ test statistics, which indicate that the differences are not significant at -1Gy or at +2Gy, but are significant at the .03 level at -2Gy. The differences at the +1Gy level were not significant. The effects were more pronounced when the subjects were being exposed to the -Gy stresses. This is attributed to the increased body loading toward the right arm, which was performing the tracking task.

Subjective Comments and Observations of Pilots

All participating pilots were given questionnaires to execute following exposure to each experimental condition. These questionnaires form the Appendix.

As might be expected of a group of test pilots, their comments are diverse, thoughtful, and extensive. Many of the comments derive from the differences between flying an airplane and riding a centrifuge and, although these are interesting and informative, the comments are not germane to this study. In reading the comments, keep in mind that the subjects were exposed to the restraints in different orders and therefore, although the comments are arrayed by subject in the order of conventional restraints first, followed by the experimental restraint comments, this is not necessarily the order in which that subject encountered the experimental conditions

Similarly, the comments relating to the differences in an individual's tracking performance should be viewed in the light of the evidence revealed by the analysis of the tracking data elsewhere in this report. Differences which did not appear significant to the subjects at the time of their exposure are shown, on analysis, to be highly significant.

In an effort to place the information contained in these questionnaires in a simpler form, Tables 1 and 2 are included. The tables list the categories of favorable and unfavorable comments made on each of the restraint systems and list the number of such comments in each category. Since there appeared to be no clear-cut advantage to the experimental restraint at ±1Gy, the tables are limited to comments made only under the stress of the ±2Gy conditions.

In summary, the tables list two favorable comments on the conventional restraint system as opposed to nine such comments in favor of the shoulder restraints system. In the category of unfavorable comments there were 21 pertaining to the conventional restraint versus 11 for the experimental restraint. The bulk of the unfavorable comments on the conventional restraint have to do with physical stress, discomfort, vision, and tracking ability as perceived.

TABLE 1. UNFAVORABLE OPERATIONAL COMMENTS AT ±2Gy

Pilot Comment	Number	
	Conventional System	Experimental System
Collarbone Pressure	2	
Calf Pressure		1
Believe Additional Restraint Required	3	
Breathing Adversely Affected	2	1
Forces on Right Arm--Adverse	2	
Visual Acuity Degraded	1	
Motion Restricted, Clothing Interference		2
Torso and Head Shifted Significantly	1	
Unable to Relax	1	
Tracking may be Difficult/Impossible	2	1
Foot Slipped off Rudder Pedal	1	
Not Very Good		1
Shoulder Pressure		1
Unable to Hold Head on Rest		1
Significant Effort Required to Maintain Body Position	1	
Knee Pressure	2	
Access to Side Panels Would be Restricted		1
Shoulders Straps Should be Wider and Softer	1	
Arm Lifted off Armrest (stick)	1	
No Improvement in Left Arm Motion		1
Uncomfortable	1	
Leg Brake Support in F-16 May Make Unnecessary		1
TOTAL UNFAVORABLE COMMENTS	21	11

TABLE 2. FAVORABLE OPERATIONAL COMMENTS AT ±2Gy

Pilot Comment	Number	
	Conventional System	Experimental System
Very Good, Necessary		1
Felt More Secure Than in Aircraft	1	
Body Position Easier to Maintain		1
Turning to Check Six Easier		1
OK Unless ±2Gy Held More Than 15 Sec	1	
Right Arm/Body Coupling Decreased		1
Less Difference Between 1Gy and 2Gy		1
Less Need to Brace with Knees		1
Pads Make Side Slip More Comfortable		1
Used Shoulder Pad for Support More Than at 1Gy		1
Dc Not Appear as Restrictive as Supposed		1
TOTAL FAVORABLE COMMENTS	2	9

Physiological Observations

During the experimental runs all subjects were continually monitored by a vertical and horizontal orthogonal lead array electrocardiogram and pulse rate via a cardiotachometer was continuously monitored. No significant cardiac events were observed during any of the runs.

Although no measurements were made of respiration rate or depth, all subjects exhibited marked changes in rate and depth of respiration with the onset of lateral acceleration, irrespective of the type of restraint system being employed. These changes can be adequately described by saying that breathing was typically suspended briefly with onset and that thereafter it was shallow and somewhat labored. None of these changes were judged to be medically significant and were probably attributable only to the pronounced muscular straining engendered by the acceleration-induced forces on the body.

Displacements of the body during $\pm$2Gy were particularly pronounced in the runs in which only the conventional restraints were used. At this level, the head was clearly displaced to the side and none of the subjects were able to bring their heads back into normal sighting position. Muscular straining tremor activity in the head and neck was commonly clearly visible. These effects were seen, irrespective of the type of restraint used, although the displacements were observably lessened with the shoulder restraints.

One subject noted some decrease in visual acuity, but it is not possible to determine whether this was caused by acceleration forces or by nystagmus brought on by the motion artifacts common to centrifugation.

CONCLUSIONS AND RECOMMENDATIONS

Shoulder Restraints

On the basis of the evidence which is available, there is good reason to believe that shoulder pads will have a beneficial effect on tracking performance stated. This conclusion is supported by observation of the extensive video tapes of the experiments, which clearly show the gross body movements of unsupported subjects being mitigated significantly by the use of the shoulder pads. On the balance of the favorable and unfavorable comments made by the pilots, the conclusion is clearly in favor of the use of whatever supporting means the cockpit layout will permit. Further development of the shoulder pad is recommended in terms of some contouring and different padding subject to tradeoffs regarding side panel visibility and access, interference with clothing and survival gear, and pilot torso mobility with respect to rearward vision ("checking six").

The question of the pilot's ability to maintain eye position within the exit pupil of the HUD when exposed to $\pm$Gy is one which could not be examined in this study since this particular problem was not a part of the experimental design. Certainly the lightweight F-16 helmet currently under development will mitigate this problem as would the incorporation of the shoulder restraints. Recommend this issue be addressed in future studies. This experiment has yielded clear evidence that all pilots used both the rudder pedals and the stick to brace themselves. The next scheduled experiment will provide additional data on this topic, but it is already clear that this situation will have to be dealt with in restraint design.

In summary, this series of experiments has shown that the $\pm$1Gy acceleration environment is not particularly stressful. If the AFTI/F-16 is control-law limited to that level, then additional restraints would probably not be required. The $\pm$2Gy acceleration environment has been seen to be significantly more adverse and, given the evidence available at present, it is concluded that an improved restraint is indicated.

Tracking Performance

Because of the small pilot population, the ad hoc nature of the experimental conditions, and the short, intense schedule during which the experiments were conducted owing to the necessity for a quick response to the General Dynamics airframe design group, it is recommended that no

decisions be taken solely upon the tracking performance of the participating pilots. With these caveats in mind it is nevertheless informative to note the significant improvement in tracking performance seen with the combination of shoulder pads and the -2Gy stress. These limited data give an indication that the execution of control actions is more precise when the right shoulder restraint assists in relieving the controlling arm from some of the G induced forces. This evidence reinforces the recommendation for inclusion of the experimental restraint.

Observations of Pilots

The preponderant adverse commentary by the pilots on the conventional restraint is verified by a non-parametric analysis which indicates that under the conditions of this experiment, it can be stated with 90% confidence that the experimental restraint is superior. Examination of the pilot comments shows that the adverse comments have to do almost entirely with the high degree of discomfort experienced in the sustained ±2Gy environment without the shoulder pads. Secondarily, they pertain to the interference with control imposed by lateral loads on the right arm without the shoulder pads. This latter consideration complements the evidence of the tracking performance data, and adds additional weight in favor of the inclusion of the canopy rail mounted shoulder restraint.

Recommendation

On the basis of the evidence gathered in this experiment it is recommended that the design of the adjustable and retractable canopy rail mounted shoulder restraint should proceed.

APPENDIX

Subjective Comments and Observations of Pilots

CONVENTIONAL RESTRAINT

What is your impression of this restraint:

at 1 G to the left - Satisfactory

at 1 G to the right - Same

at 2 G to the left - I was able to cope; however, there was appreciable pressure on the left collarbone from the left shoulder strap and the forces on the left leg calf were high.

at 2 G to the right (commentary continues) If this level is to be used frequently, additional restraint would be required. The eye position was displaced several inches, which did not significantly degrade the tracking task. All body muscles were tensed in interest of bracing and attempting to become rigid. It seemed natural to breathe in short pants vs. deep breaths.

OTHER COMMENTS

To the right, the forces seemed higher and there was a slight degradation in visual acuity. When the right side force was reduced there was a lingering sensation of being rotated (in a horizontal plane) clockwise at about 45 degrees/second for one to two 360-degree turns. This sensation was not apparent when recovering from the "left" runs. This disorienting effect during entry and exit from the side force excursions was markedly minimized by concentrating on the tracking task. Also it seemed better to maintain the 18 RPM in between the 2 G runs.

SHOULDER PAD

What is your impression of this restraint:

at 1 G to the right - Slightly helpful

at 1 G to the left - Same

at 2 G to the right - Very good. In fact, necessary for the task at hand.

at 2 G to the left - Same

Did you vary the pad location during any runs? No

Was the pad the optimum size, shape, etc.? Size OK, could possibly be better contoured to arm.

OTHER COMMENTS

With regard to operational considerations, I think, the time at 2G Ay will be very limited; perhaps a smaller restraint would be satisfactory. The configuration evaluated is likely to be objectionable or over restrictive to the body motions for conventional operations. With winter flight gear or LPUs for over-water operations, there will probably be some interference problems. The pads do a good job for 2G Ay, but realistically I don't think 2G Ay will be used much, especially for an extended steady-state period.

CONVENTIONAL RESTRAINT

What is your impression of this restraint:

at 1 G to the left - Able to relax in the straps, breathe normally, and track satisfactorily; did not miss the absence of the pad; did not become disoriented.

at 1 G to the right - Same

at 2 G to the left - Upper torso and head shifted significantly--suspect tracking through (sic) and may be impossible; unable to relax; difficulty in breathing. M-1 maneuver did not work.

at 2 G to the right - (commentary continues) Very disorienting throughout all side force applications (suspect due to large head displacement); felt some support of upper torso and head necessary; canopy rail may be satisfactory (need to check in mockup).

OTHER COMMENTS

1. Noted no difference between right and left forces.
2. Left foot slipped off of rudder pedal with +2G(Ny).
3. Felt more secure with lap belt/harness restraint in the centrifuge than I do in everyday aircraft flying. May be more reason to have some form of support.
4. Tracking task was easier (higher up on learning curve)

SHOULDER PAD

What is your impression of this restraint:

at 1 G to the right - Very good; was able to manipulate hands on stick and throttle; head stayed steady and could look out at HUD/track target; shoulder pads appear very promising.

at 1 G to the left - Same

at 2 G to the right - Not very good; felt single pressure points--one at shoulder and one at mid-calf; the forces on the shoulder for the length of time (15 seconds) became disconcerting.

at 2 G to the left - (comment continues) Tracking was more difficult; breathing became more difficult. Vertigo/disorienting when transitioning to Ny loads.

Did you vary the pad location during any runs? No, but it did come loose/shift during one maneuver.

Was the pad the optimum size, shape, etc.? The right shoulder pad came loose on the second maneuver. I am suspect that the pad's shape is not optimum, and could be more contoured for the shoulder. The size and position appear satisfactory.

OTHER COMMENTS

1. During build-up work while experiencing G forces up to 6 Gs I became extremely disoriented with either side-to-side rotational head movements. Became nauseous after 5 to 6 of the rotational (check six) excursions.
2. Duing the 1 G lateral accelerations, the return to 0G (Ny) was disorienting. Felt that I was experiencing about 0.5G (Nz). I stopped after the fifth 1G acceleration due to nauseous feeling.
3. Performed 2G (Ny) evaluation during second run.
4. Head on headrest did not make any significant difference on tracking ability [during 2G (Ny), unable to hold head on the rest].

CONVENTIONAL RESTRAINT

What is your impression of this restraint:

at 1 G to the left - comfortable and sufficient

at 1 G to the right - A little more effort required, but no degradation of performance noted.

at 2 G to the left - Significant effort required to maintain body position. Some discomfort with shoulder strap across left collarbone.

at 2 G to the right - Same general effect, but overall a more difficult task due to requirement to maintain right arm position for tracking; could not lean on elbow, for example.

OTHER COMMENTS

1. Note comments on test tape/audio
2. Transitions to lateral Gs gave worst tracking accuracy
3. Ability to track seemed to improve with time in the environment
4. Lateral leg restraints (metal on seat) were judged to be an aid in maintaining body position; however, the protrusion just below my knee was annoying.
5. Cooper-Harper--1 G left and right--8 for restraints
   7 for task overall

   2 G left--5 for restraints and task
   2 G right--4 for restraints
   5 for task

SHOULDER PAD

What is your impression of this restraint:

at 1 G to the right - Comfortable but no significant improvement over yesterday (shoulder straps only).

at 1 G to the left -

at 2 G to the right - Body position was easier to maintain for the most part, except for the head; more neck effort was required to hold the head up.

at 2 G to the left - (commentary continues) I felt I could not get "under" my head as easily as before.

Did you vary the pad location during any runs? No

Was the pad the optimum size, shape, etc.? No. Size and shape seemed all right but placement does not allow access to the side instrument panels in the F-16 aft of the stick and throttle.

OTHER COMMENTS

1. Refer to data tape.
2. Size is important. Vision to the side panels in the F-16 is poor now; and restriction to the view of these panels should be considered carefully.
3. Turning to look to the rear was easy with pads.
4. Unless the duration of the lateral 2 Gs would exceed 15 seconds, I think a more supportive shoulder strap (wider and softer) would be preferable to the side restraints.

CONVENTIONAL RESTRAINT

What is your impression of this restraint:

at 1 G to the left - I was able to hang in the straps without excessive hindrance to control inputs.

at 1 G to the right - Able to hang in the straps but arm was lifted off of the right armrest. Throttle control was unaffected by left arm motion.

at 2 G to the left - Transition into (and out of) the side load condition caused the largest impact on tracking. I was still able to hang in straps.

at 2 G to the right - This condition had the largest effect on right arm position. Right arm was off of armrest.

OTHER COMMENTS

Left arm was not significantly hindered during any of the test conditions. I tended to put pressure on both knee guards during the 2 G test points. The sideslips where my body was pushed to the right caused the greatest body coupling. On the right turns, I began to compensate by lifting my right arm as soon as the sideslip was initiated. There is some loss in the validity of this test because of the smooth flat armrest; the F-16 cockpit has the curved armrest and the bulkhead. They can be used to brace the arm.

SHOULDER PAD

What is your impression of this restraint:

at 1 G to the right - Upper body motion is minimized; therefore, body coupling with sidestick is minimized.

at 1 G to the left - There is not as big a tendency to raise my arm as with the normal restraint system.

at 2 G to the right - The difference from 1 G to 2 G is less significant when the pads are installed.

at 2 G to the left - Right arm/body coupling is decreased with the shoulder pads.

Did you vary the pad location during any runs? No

Was the pad the optimum size, shape, etc.? I would need a lot of time to optimize the size and shape of the pad. If we do use the pads, I would feel that a slightly larger, concave pad would be better.

OTHER COMMENTS

1. Control of left hand was good on all runs. There does not seem to be a difference between left and right sideslip. The shoulder support does not yield an improvement in left arm motion over the normal aircraft restraint system.
2. Although the ride was more comfortable, I did not see an improvment in the tracking task. Without the pads, I braced myself by spreading my knees; there was a much smaller tendency to lock my knees against the knee guards. When I raised my feet to the bulkhead my knees were too high on the knee guard to allow me to brace myself. With the raised foot position in the F-16, I do not believe that the pilot would be able to easily brace himself with his knees.
3. The right armrest does not resemble the cockpit armrest; therefore, there is some loss in validity of the experiment.
4. Both of the pads would restrict motion in the cockpit. That will present a problem in the F-16 because the seat sits high in the cockpit, the consoles are difficult to see and reach. It is necessary to use the towel racks to see all of the switches. This restriction to motion will limit easy access to side panels.

"Bottom Line"

1. Pads do not significantly improve tracking.
2. Pads limit easy access to side consoles.
3. Pads limit body motion which will restrict head motion and rearward visibility.
4. Pads make the sideslip more comfortable.

CONVENTIONAL RESTRAINT

What is your impression of this restraint:

at 1 G to the left - No difference noted left and right. Primary support was my elbow. Shoulder pads are probably incidental.

at 1 G to the right -

at 2 G to the left - Some sort of support is required. Legs, buttocks, and shoulder straps were used to obtain sufficient support; uncomfortable.

at 2 G to the right - Same combination of support required as for left; fairly difficult to displace tracking symbol to right. Uncomfortable to rest against strap.

OTHER COMMENTS

I completed two runs at 4 Gs Nz and generated about 1 1/3 Gs laterally during tracking. (Note: During this experiment Mr. Ishmael was in control of the centrifuge cab axis and could command lateral G with the sidearm controller). No slipping in the seat was noticed. Elbow support was totally sufficient to offset side force. Side force was almost unnoticed.

Conclusion

I suspect that shoulder pads are unnecessary at typical (3-5 Gs) inplane load factors.

SHOULDER PAD

What is your impression of this restraint:

at 1 G to the right - I had to reposition my body to raise my right arm a little so that I could move my elbow during tracking. The pad was about 2 inches too high for me.

at 1 G to the left - I took about 5 seconds to settle on my left shoulder before resuming tracking. I used my legs more than shoulder for support.

at 2 G to the right - I used the shoulder pad for support more than during 1 G. The effort required for head support was as noticeable to me as bracing for the overall acceleration.

at 2 G to the left - (no comment on leftward, commentary continues). It required considerable compensation to continue target tracking during G onset.

Did you vary the pad location during any runs? No

Was the pad the optimum size, shape, etc.? It was a little too low, 2 inches.

OTHER COMMENTS

I suspect that the utility of side force during tracking depends on a rather extensive learning curve. The pads do not appear as restricitve as I thought they would be. The availability of leg brace support in the actual cockpit may obviate the need for shoulder support.

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